The Economics of Reprocessing in the United States

Testimony of
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Committee on Science
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Madam Chairwoman and Members of the Committee:

It is an honor to be called before you to discuss the subject of nuclear fuel reprocessing – a matter of considerable importance to the future of nuclear energy, as well as to the effort to prevent the further spread of nuclear weapons.[1]

Closing the nuclear fuel cycle – that is, reprocessing spent nuclear fuel and recycling the recovered plutonium – has been a dream of many in the nuclear industry from its earliest days. Here in the U.S. that dream has long been elusive, but lately it has been rekindled as attention focuses once more on the future role of the nuclear industry in meeting our nation's energy needs. I believe that a major expansion of nuclear power will almost certainly be necessary if our industries, offices, and homes are to be assured of access to adequate supplies of energy at reasonable cost and with proper regard for the environment, especially given the crucial need to curtail carbon dioxide emissions. However, in my judgment an attempt to introduce spent fuel reprocessing here in the U.S. in the near term would not only not help to ensure a greater role for nuclear power but might actually make this outcome less likely.

Spent nuclear fuel from commercial light water reactors typically contains about 1% of plutonium. Recovering this plutonium and recycling it in so-called MOX or mixed uranium-plutonium oxide fuel would reduce the requirement for natural uranium ore by about 17% and the requirement for uranium enrichment services by a similar amount. But the operations needed to accomplish this – reprocessing and the fabrication of mixed-oxide fuel – are costly, and adopting them would cause an increase in the overall cost of nuclear electricity relative to the open or once-through fuel cycle with direct disposal of spent fuel. There is no disagreement about this, although opinions differ as to how large the cost penalty would be. But given that unfavorable economics has been one of the main barriers to nuclear energy investment for decades, and that it remains a major issue today, any proposed course of action that would result in an increase in nuclear generating costs should be viewed with caution.

Those who advocate near-term reprocessing make three arguments in response to these concerns:

First, that the closed fuel cycle is indeed more costly, but that the cost penalty is not large, and so we should not worry too much about it.

Second, that although the closed fuel cycle is more expensive than the open cycle under current economic conditions, in the future this comparison is likely to be reversed.

Third, that the economic penalty associated with reprocessing and recycle is outweighed by the non-economic benefits that would accrue. In the past, advocates of reprocessing have emphasized its contributions to extending fuel supplies and to energy supply security. Today the principal claim is that reprocessing will facilitate and simplify the management and disposal of nuclear waste.

These arguments are superficially attractive, but on closer analysis none of them carries real weight. Indeed, the preponderance of evidence in each case points in the opposite direction, to the need to avoid the

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[1] A previous hearing of this Subcommittee reviewed the security aspects of reprocessing. In this testimony I focus on the economic dimension.

implementation of reprocessing in the near-term. I will briefly comment on each point in turn.

First, how large is the cost penalty associated with reprocessing and recycle likely to be? An exact answer is not possible, because some of the most important contributing factors are uncertain or otherwise difficult to estimate. The biggest source of uncertainty, with the largest impact on overall cost, is associated with reprocessing itself. Other important uncertainties center on the cost of MOX fuel fabrication, and the cost of disposing of reprocessed high-level waste relative to the direct disposal of spent fuel.

Under current economic conditions, and making generally optimistic assumptions about how much reprocessing and MOX fabrication services would cost were they to be available in the U.S., I estimate that a U.S. nuclear power plant opting to use these services would incur a total nuclear fuel cycle cost of about 1.8 cents per kilowatt hour of electricity. By comparison, the total cost of the once through fuel cycle is a little under 0.6 cents per kilowatt hour. In other words, nuclear power plants operating on the closed fuel cycle would experience a nuclear fuel cycle cost increase of about 300%. Since fuel cycle expenses account for about 10% of the total cost of nuclear electricity from unamortized nuclear power plants (capital-related costs account for most of the remainder), this would be equivalent to an increase of about 20% in the total nuclear generation cost.[2]

In this analysis, disposing of reprocessed high-level waste was assumed to be 25% less expensive than disposing of spent fuel directly. In fact, there can be little confidence today in any estimate of such cost savings, especially if the need to dispose of non-high-level waste contaminated with significant quantities of long-lived transuranic radionuclides generated in reprocessing and MOX fabrication is also taken into account. But even if the cost of disposing of reprocessed high-level waste were zero, the basic conclusion that reprocessing is uneconomic would not change.

The impact of reprocessing is often expressed in terms of the *average* cost for the entire fleet of nuclear power plants. The usual assumption is that the fleet would be configured so as to be in balance with respect to plutonium flows, with just enough power plants using MOX fuel to consume all the plutonium recovered by reprocessing the spent fuel from the rest of the plant population. In that case, and using the same economic assumptions as before, the effect of reprocessing and plutonium recycle would be to increase the fleet-average fuel cycle cost by about 0.23 cents/kilowatt hour, or about 40%. The total nuclear electricity cost would increase by about 4%. However, while fleet-averaging may be appropriate for a centrally-planned nuclear power industry like that of, say, France, where the enforcement of cross-subsidy arrangements ensuring uniformity of cost impacts across the entire industry is perhaps plausible, this would not be the case in the U.S. Here, in the absence of a direct federal subsidy, nuclear plant owners opting for the closed fuel cycle would either have to absorb the entire cost increase themselves or pass part or all of it on to their customers. In the competitive wholesale regional power markets in which many U.S. nuclear power plants operate, it is unlikely that either option would be attractive to plant owners.

Could today's negative economic prognosis for reprocessing be reversed in the future? For at least the next few decades this seems extremely unlikely. For example, even with the same optimistic assumptions for reprocessing and MOX fabrication costs as before, the purchase price of natural uranium would have to increase to almost $400/kg for reprocessing to be economic. By comparison, the average price of uranium delivered to US nuclear power reactors under long-term

[2] In this analysis, the cost of reprocessing is assumed to be $1000 per kilogram of heavy metal in spent fuel. This is an optimistic assumption, and is considerably lower than the estimate made by Matthew Bunn and his colleagues for a new reprocessing plant with the same technical and cost characteristics as BNFL's Thermal Oxide Reprocessing Plant (THORP) at Sellafield in the UK. (See Matthew Bunn, Steve Fetter, John Holdren, and Bob van der Zwaan, "The Economics of Reprocessing versus Direct Disposal of Spent Fuel", Project on Managing the Atom, Kennedy School of Government, Harvard University, December 2003.) Any new reprocessing plant committed for construction for at least the next decade would necessarily be modeled closely on the PUREX technology employed at THORP and at the French fuel cycle firm Areva's reprocessing complex at La Hague. According to the Harvard study, the cost at such a plant would range from $1350 to $3100 per kilogram, depending on the financing arrangements used. The low end of the range assumes a government-owned plant, with access to capital at risk-free interest rates; the upper end would apply to a privately-owned plant with no guaranteed rate of return on investment. Reports over the last few years indicate that reprocessing contracts offered by THORP and by Areva's UP-3 reprocessing plant at La Hague have recently been in the $600-$900 per kilogram range. But both of these plants have now been fully amortized, and the offered prices are believed only to cover operating costs. Earlier contracts at these plants, for which the price included a capital cost recovery component, were reportedly in the $1700 - $2300/kg range (see Bunn et al, op.cit.) Thus the $1000/kg cost assumed here is conservative even with respect to past experience. Moreover, future reprocessing plants would almost certainly be required to meet more stringent and hence more costly safety and environmental specifications than the plants at Sellafield and La Hague, including a zero-emission requirement for gaseous fission products and the need to harden facilities against the risk of terrorist attack.

contract during 2004 was about $32/kg.[3] In recent months uranium prices have moved sharply higher, with long-term contract prices as of mid-May reportedly exceeding $70/kg. But this is still far below the breakeven price of $400/kg. Alternatively, could reprocessing costs decline to the point at which MOX fuel would be competitive with low-enriched uranium fuel? At current uranium prices the cost of reprocessing would have to fall below about $260/kgHM, a reduction of about 75% relative to the (already optimistic) reference reprocessing cost assumed here. In neither of these scenarios do the necessary price movements fall within the bounds of the credible.

Indeed, the needed reduction in reprocessing costs would be particularly implausible given a requirement to select a specific reprocessing technology for large-scale implementation as early as 2007, as is called for in recent House legislation. This requirement would effectively force the adoption of the PUREX technology that is currently in use in France, the United Kingdom, and Japan, since no alternative would be available on that timescale. And there is simply no possibility of achieving a cost reduction of 75% -- or anything close to it -- for this relatively mature technology.

A similar point can be made about the waste management implications of reprocessing. The selection of PUREX reprocessing technology would not fundamentally change either the impending problem of inadequate interim spent fuel storage capacity or the problem of finding a suitable site for final waste disposal. The need for additional storage capacity and for a final repository, whether at Yucca Mountain or elsewhere, would still remain.

Advanced reprocessing technologies, if coupled with transmutation schemes, could in principle improve the prospects for successful disposal. Such schemes would partition plutonium and other long-lived actinides from the spent fuel – and possibly also certain long-lived fission products – and transmute them into shorter-lived and more benign species. The goals would be to reduce the thermal load on the repository, thereby increasing its storage capacity, and to shorten the time for which the waste must be isolated from the biosphere. It is important for research to continue on advanced fuel cycle technologies potentially capable of achieving these goals will be important to pursue. But even in the best case these technologies are not likely to be available for large-scale deployment for at least two or three decades. Indeed, there is no guarantee that the desired performance objectives could be achieved on any timescale. The eventual economic impact of such schemes cannot now be predicted with confidence. But the strong likelihood is that they would be more costly than conventional PUREX reprocessing and MOX recycle, since they would entail more complex separations processes, more complete recovery of radionuclides, a more complex fuel fabrication process, and the need to transmute a broader array of radionuclides than just the plutonium isotopes.

The MIT Study on the Future of Nuclear Power considered a range of advanced fuel cycle options from a waste management perspective, and reached the following conclusion:[4]

"We do not believe that a convincing case can be made on the basis of waste management considerations alone that the benefits of advanced, closed fuel cycle schemes would outweigh the attendant safety, environmental, and security risks and economic costs."

The MIT report further concluded that waste management strategies in the open fuel cycle are available that could yield long-term risk reduction benefits at least as great as those claimed for advanced reprocessing and transmutation schemes, and with fewer short-term risks and lower development and deployment costs. These strategies include both relatively incremental improvements to the currently preferred approach of building mined geologic repositories as well as more far-reaching innovations such as deep borehole disposal.

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For all these reasons, as well as others I have not discussed here, including the adequacy of natural uranium resources and the risks of nuclear weapons proliferation, the MIT Study concluded that reprocessing and MOX recycle is not an attractive option for nuclear energy for at least the next fifty years, even assuming substantial expansion of the nuclear industry both here in the U.S. and overseas, and that the open, once-through fuel cycle is the best choice for the nuclear power sector over that period. The report recommends that:

"For the next decades, government and industry in the U.S. and elsewhere should give priority to the deployment of the once-through fuel cycle, rather than the development of more expensive closed fuel cycle technology involving reprocessing and new advanced thermal or fast reactor technologies."

[3] Energy Information Administration, "Uranium Marketing Annual Report – 2004 Edition", release date: 29 April 29 2005, at http://www.eia.doe.gov/cneaf/nuclear/umar/umar.html.

[4] MIT Study Group, *The Future of Nuclear Power,* Massachusetts Institute of Technology, 2003.

Research on advanced reprocessing, recycling, and transmutation technologies should certainly continue. A closed fuel cycle will be necessary if fast-neutron breeder reactors ever become competitive. But that does not seem likely for the foreseeable future, and for now the primary goal of fuel cycle research should be to maximize the economic competitiveness, the proliferation resistance, and the safety both short and long term of the once-through fuel cycle.

What if, in spite of these arguments, Congress still seeks to intervene to stimulate large scale reprocessing in the near term? Because a purely private initiative would be economically unviable, such an intervention, to be effective, would inevitably require a major commitment of federal funds.[5] The need for direct government involvement would also place heavy demands on the government's nuclear-skilled human resources, who would necessarily be involved in the selection of a site, the development of a licensing framework, the management of contractors, and so on. The resources – both human and financial – that are potentially available to the government to support the development of nuclear power are not unlimited. A new federal reprocessing initiative would therefore risk diverting resources from other policy initiatives that are likely to make a greater positive contribution to the future of nuclear power over the next few decades.

[5] A large new reprocessing facility using the same PUREX technology now in use in France and the UK would cost several billion dollars to build. The capital cost of the new Japanese PUREX reprocessing plant at Rokkasho-Mura reportedly exceeds $20 billion.